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SIMPLE HYDROGEN-BEARING MOLECULES IN TRANSLUCENT MOLECULAR CLOUDS

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Abstract. We demonstrate relations between column densities of simple molecules: CH, CH^+, H_2 and OH. The H_2, CH and OH molecules seem to occupy the same environments because of tight relations between their column densities. In contrary to this CH^+ column density does not correlate with those of other simple molecules.

1 Introduction

Molecular hydrogen H_2 is the most abundant molecule in the interstellar medium (ISM) with column densities exceeding 10^{19} cm^{-2} toward examined OB stars; its ultraviolet spectrum may be detected only by spaceborn instruments. Spectra of translucent clouds are also characterized by features of other simple molecules such as CH, CH^+, OH, NH, and CN available to ground-based telescopes.
Recently it was shown by Weselak et al. (2008a) that column densities of H_2 and CH^+ show large scatter suggesting no relation between these two molecules. On the other hand CH molecule is closely related to molecular hydrogen (Mattila 1986, Weselak et al. 2004). Also the relation between column densities of the CH and OH molecules is very good (Weselak et al. 2009).
Here we present relations between column densities of simple hydrogen-bearing molecules (H_2, CH, CH^+, OH). The observational material is based on high resolution and high S/N ratio observations using five echelle spectrographs. Column densities of the H_2 molecule were obtained from the literature.

2 The Observational Material

Our observing material was acquired using five echelle spectrometers:

- MAESTRO fed by the 2-m telescope of the Observatory at Peak Terskol (see http://www.terskol.com /telescopes/3-camera.htm)
- Feros spectrograph, fed with the 2.2m ESO telescope in Chile (see http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/)

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- fiber-fed echelle spectrograph installed at 1.8-m telescope of the Bohyunsan Optical Astronomy Observatory (BOAO) in South Korea
- HARPS spectrometer, fed with the 3.6m ESO telescope in Chile (see http://www.ls.eso.org/lasilla/sciops/3p6/harps/)
- UVES spectrograph at Paranal in Chile. For more information see: http://www.eso.org/sci/facilities/paranal/instruments/uves

To obtain column densities we used the relation of Herbig (1968) which gives proper column densities when the observed lines are unsaturated:

$$N = 1.13 \times 10^{20} W_\lambda / (\lambda^2 f), \tag{2.1}$$

where W_λ and λ are in Å and column density in cm^{-2}. To obtain column density we adopted f-values listed in Table 1.

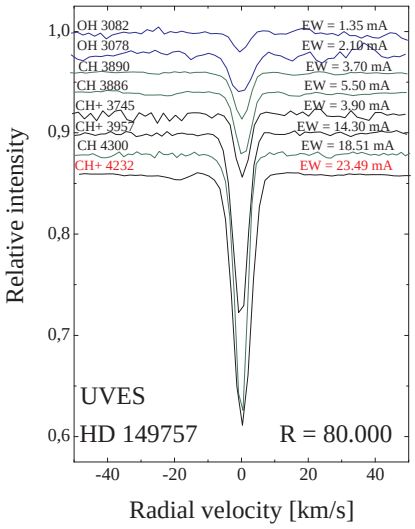

Fig. 1. Interstellar features of the OH, CH and CH^+ molecules (presented in Table 1) in the spectrum of HD 149757. The CH^+ line at 4232 Å is saturated. In this case to obtain column density we used the unsaturated CH^+ line at 3957 Å.

Table 1: Adopted molecular parameters. References: 1 – Weselak et al. (2009b), 2 – Felenbok and Roueff (1996), 3 – Gredel et al. (1993), 4 – Weselak et al. (2009a), 5 – van Dishoeck and Black (1986)

Species	Vibronic band	Rotational lines	Position [Å]	Ref.	f-value	Ref.
OH	$A^2\Sigma^+ - X^2\Pi_i$ (0, 0)	$Q_1(3/2)+^Q P_{21}(3/2)$	3078.443	1	0.00105	2
	(0, 0)	$P_1(3/2)$	3081.6645	1	0.000648	2
CH	$A^2\Delta - X^2\Pi$ (0, 0)	$R_{2e}(1) + R_{2f}(1)$	4300.3132	3	0.00506	5
	$B^2\Sigma^- - X^2\Pi$ (0, 0)	$Q_2(1)+^Q R_{12}(1)$	3886.409	3	0.00320	3
	(0, 0)	$^P Q_{12}(1)$	3890.217	3	0.00210	3
CH^+	$A^1\Pi - X^1\Sigma^+$ (0, 0)	R(0)	4232.548	3	0.00545	3
	(1, 0)	R(0)	3957.689	4	0.00342	4
	(2, 0)	R(0)	3745.308	4	0.00172	4

3 Results

1. The CH cation seem to be formed in other reaction pathways since their column densities do not correlate with those of H_2 and OH (Figs 2a and 2b).

2. The column densities of both OH, CH and H_2 molecules are closely related as seen in Figs 3a and 3b. This relation suggests that both species originate and are preserved in the same environments. One atypical object, HD 34078, misses the relation between column densities of OH and CH molecules and also between the column densities of CH and H_2 molecules.

3. Interstellar molecules such as H_2, CH and OH seem to be closely connected in translucent clouds. The CH molecule may be used as an OH and H_2 tracer, as its features are easily accessible and well–related to the abundances of hydrogen and hydroxyl.

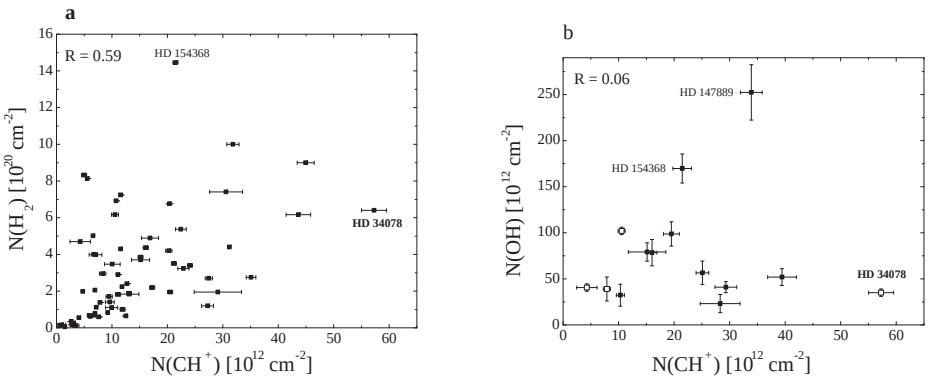

Fig. 2. The poor relation between column densities of CH^+ and H_2 molecules (a) and also between the column densities of OH and CH^+ (b). Correlation coefficients are presented at the top-left in each case.

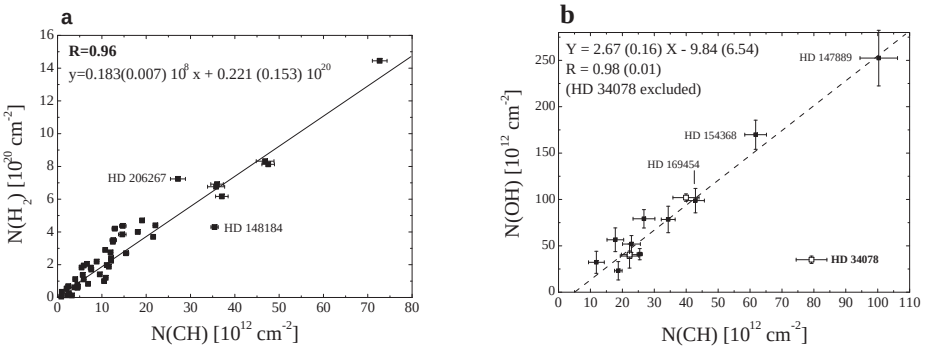

Fig. 3. The very good relation between column densities of H_2 and CH molecules (a) and also between the column densities of OH and CH (b). With the dashed line we present the relation with one data-point excluded (HD 34078).

4 Acknowledgements

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